

Pioneer Venus Wind Experiment Receiver

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The final design of the Pioneer Venus Wind Experiment Receiver and Phase Calibrator is discussed from the block diagram viewpoint. Measured phase data are shown to derive the predicted performance. The STDN receiver implementation is also discussed.

I. Introduction

The Pioneer Venus 1978 (PV 78) project consists of an orbiter and a multiprobe Mission. The orbiter will be inserted into a Venusian orbit with a mission lifetime of 243 Earth days. The multiprobe portion consists of a bus and four aerodynamic probes which are delivered into the Venusian atmosphere (Ref. 1). One of the experiments to be conducted by the probe descent phase consists of relative wind drift measurements. The five signals from the probes and bus will be received by open-loop receivers located at DSS 14 and DSS 43 and STDN receivers located on the island of Guam and in Santiago, Chile. This article will concentrate on the design requirements and characteristics of the DSN Wind Experiment Receiver plus a short discussion of the modification of the existing STDN receivers for use in the wind experiment.

II. Requirements

The electrical requirements for the DSN receiver are shown in Table 1. Included are the requirements for the phase calibra-

tor which is used to measure and correct receiver phase variations. The receiver will be connected to the output of the traveling wave maser (TWM) amplifier.

III. Description

A. Overall Block Diagram

Figure 1 shows the simplified block diagram of the overall DSN receiver including the calibrator. Isolators, attenuators, and most of the amplifiers and filters have been deleted from the diagram to facilitate the overall description.

The Wind Experiment Receiver is an open-loop, constant-gain receiver which accepts the S-band carriers of the Pioneer Venus probes. The information bandwidth of 2 MHz was selected on the basis of the predicted doppler excursion of the four descending probes and bus — including the spare probe and the redundant bus frequencies, if required. Also included in this passband are the phase calibration signals which are located at the outer edges of the band. Wind drift measure-

ments will be accomplished by long baseline differential interferometry (DLBI) and the conventional doppler frequency spacecraft tracking methods. The DLBI method is an earth-based observation for obtaining the probes' and bus's relative velocities. Three velocity components are obtained for these measurements: (1) An angular velocity component relative to the earth-based two-station baseline, (2) another angular velocity component orthogonal to the first due to the additional two-station baseline, and (3) the radial velocity component relative to the earth. The first component is determined by measuring the differential time delay of a given probe's signal received and recorded by two tracking stations (DSN receivers). The second is determined by two orthogonally located baseline stations (STDN receivers) which receive and record the signal in a similar manner. The angular velocities are determined after cross-correlating the recorded data of the two-station pairs. The radial velocity component is determined by the doppler shift of the recorded probes' and bus frequencies after processing. The bus's relative velocity to the planet Venus is obtained by the conventional two-way doppler utilizing closed loop receivers.

Hence, the resultant information obtained is the relative velocities of the probes and the bus to each other and to the planet Venus as a function of time.

Basically, the receiver is a double conversion device capable of accepting an input between 2245 and 2345 MHz and an output in the 100-kHz to 2-MHz frequency range. In order to provide accurate determinations of the two angular velocity components, two differentially phase stable calibration signals are injected into the front end of the receiver. These signals, which are stable with respect to each other to within one degree of phase, provide a measurement of the phase delay variations from one edge of the band to the other.

The composite signal, consisting of the carriers and the calibration tones, is recorded. For an additional calibration of phase of the overall ground tracking system before and after tracking, provision is made for the injection of the calibration signals into the system before the TWM.

In Fig. 1, the antenna and control room portions of the receiver are shown separately and interconnected by low-loss coaxial cables. In general, the higher frequency S-band sections are located in the antenna to minimize the front end losses. The IF and lower frequency circuits are in the control room.

B. Main Signal Channel

The block diagram shows the S-band probe carriers entering the TWM. At its output the S-band signals are distributed to the telemetry receivers and to the Wind Experiment Receiver's

first mixer (MIX) input. The signals are down-converted by a 2000-MHz phase-stable first LO to an intermediate frequency of 292 MHz. The first IF amplifier (IF AMP) provides enough gain to drive the single sideband mixer (SSB MIX) located in the control room. The band pass filter (BPF) is designed for a 100-MHz bandwidth and assures a linear phase delay at the probe carrier frequencies. SSB MIX has a 30-dB image rejection and 2-deg peak-to-peak phase ripple. SSB MIX is driven by a 291-MHz second LO, which is derived by multiplying the synthesizer output frequency. Output rejection is provided by a Tchebycheff low-pass filter (LPF) which is phase-equalized to within 10% of linearity.

C. First Local Oscillator

For the purpose of achieving a significant improvement in phase stability, the times-20 frequency multiplier (X20) and the coaxial 100-MHz cable connected at the reference input of the X20 are both phase-stabilized. The X20 is a commercial phase-locked design driven by an external reference frequency of 100 MHz. Like most multipliers, the long-term phase stability is a function of the ambient temperature. The overall phase drift is lowered from 60 to 2.5 deg of phase by placing the unit within a temperature-controlled component oven with an internal temperature of $60 \pm 0.12^\circ\text{C}$. The coaxial cable employs a cable stabilizer circuit at each end of its length to minimize its phase variations. Measurements of long lengths of uncompensated cables which are exposed to external station environment have shown that phase changes at radio frequencies are particularly severe during the night-day and day-night transitions as the cables are heated or cooled. The stabilizer circuit reduces the expected phase variations from 76 to 5 deg of phase. The circuit consists of a phase-locked loop which senses phase variations at the terminating end of the cable and appropriately corrects a voltage-controlled phase shifter at the source end of the cable.

D. Calibrator

The calibrator generates the differentially phase stable calibration signals at S-band. The circuit is based on the Haystack Observatory method of generating a broadband of pulses from a tunnel diode generator. The diode is driven by a phase-stable 5.4-MHz square wave. As the pulses emerge from the diode, a diode switch gates the output at 1.8 MHz, the approximate frequency spread required for the calibration signals at S-band. At S-band, these signals, which are positioned at the extremities of the overall bandwidth, are at 2291.1 and 2292.9 MHz. During track, the calibrator switch is placed in the operational mode and calibration signals are injected into the S-band line after the microwave distribution assembly, but before the receiver's first mixer. This method prevents interfering phase calibration pulses from being coupled into the telemetry receivers.

The 5.4-MHz square wave is derived from the output of a divide-by-8 ($\div 8$) circuit. The $\div 8$ is driven from synthesizer SYNTH 1 at 43.2 MHz, which is referenced to the 100-MHz hydrogen maser.

E. Pre/Post Tracking Calibration

As shown in Fig. 1, the pre/post calibration circuits utilize the original calibration drive frequency of 43.2 MHz and compare its phase after frequency division to the phase of the calibration signals recovered at the receiver output. The result gives a measure of the phase stability of the overall ground system before and after tracking. Note that the calibration switch is placed in the PRE/POST CAL position during the tests to permit calibration signals to be injected ahead of the TWM.

The 43.2 MHz from SYNTH 1 is divided by a factor of 24 to obtain 1.8 MHz, the same pulse repetition rate of the two calibration signals. The 1.8 MHz is applied to the reference input of the phase meter.

At the receiver output, the calibration signals are recovered, then mixed, to obtain the difference product at 1.8 MHz. This second 1.8-MHz signal is also applied to the phase meter for a phase comparison with the reference.

F. Phase Stability

Table 2 shows phase stability data of the major components within the receiver. Except where indicated as estimated, the data were measured at the expected operating frequencies. The calibrator data was obtained from a Haystack report (Ref. 2).

The table is divided essentially into two areas. The left two columns contain phase information under assumed room temperature variations, $\pm 3^\circ\text{C}$, and with no first LO cable stabilization. The right two columns are with $\pm 0.12^\circ\text{C}$ oven temperature control on the first LO and with cable stabilization of the first LO cable. The columns headed "2-hr" and "4-hr" refer, respectively, to mission duration and to the interval between calibrations.

G. STDN Receiver

The existing STDN S-band receivers (Fig. 2) are being modified to satisfy the requirements of the wind experiment. Since STDN is not committed to providing probe telemetry, the calibration signals will be injected into the S-band signal line before the parametric amplifier. Operational and pre/post calibration measurements will be conducted from a single injection point. The first LO and mixer of the STDN receivers remain unchanged. An output from the STDN distribution coupler provides a 492-MHz IF to the added-on wind experiment receiver. This signal is amplified by amplifier IF AMP and down-converted by a single-sideband mixer, the same unit as used in the DSN receivers. The composite output signal is sent to the A-D converter. The output can also be phase-compared for pre/post tracking as in the DSN receivers.

IV. Conclusion

The design is expected to meet the PV 78 requirements for phase stability and calibration. The prototype is presently under construction using commercial parts wherever possible. The stations are expected to be operational by the middle of March 1978.

References

1. Miller, R. B., "Pioneer Venus 1978 Mission Support," in *The Deep Space Network Progress Report 42-20*, pp. 17-19, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 15, 1974.
2. "VLBI Phase and Group Delay Calibration System," Technical Note 1975-1, Haystack Observatory, Massachusetts Institute of Technology, Boston, Mass.

Table 1. Electrical requirements

Parameter	Requirement
Input signal frequency range for probe and calibration signals	2291.1 to 2292.9 MHz
Receiver noise figure	≤ 8.0 dB
Phase calibrator	
Phase stability (over four hours)	≤ 1 deg phase variation between calibration signals
Signal level	≥ 94 dBm into receiver front end via coupler
Frequencies	2291.1 to 2291.15 MHz lower calibration signal; 2292.9 to 2292.95 MHz upper calibration signal
Receiver composite output signal	
Frequency range	0.1 to 1.9 MHz
Phase ripple	2 deg peak-to-peak
Phase linearity	9-pole Tchebycheff response. Phase equalized to within 10% of linear
Amplitude response	≥ 10 dB down at 2.26 MHz

Table 2. Receiver phase stability

	No temp. control, $\pm 3^\circ\text{C}$, no cable stabilization		1st LO temp. control $\pm .12^\circ\text{C}$ with cable stabilization	
	2-hr	4-hr	2-hr	4-hr
Main signal channel				
Phase variation of one signal in passband				
H ₂ maser, 10^{-14}	60	120	60	120
Cable, 100 MHz	76	152	5	10
X20 freq. mult.	60	60	2.5	2.5
S-band mixer (est.)	2	2	2	2
IF amp and BPF	4.2	4.2	4.2	4.2
Cable, IF	6.4	12.8	6.4	12.8
Synthesizer	3.6	3.6	3.6	3.6
Freq. mult. (est.)	3	3	3	3
SSB mixer and LPF	0.6	0.6	0.6	0.6
Video amp.	0.4	0.4	0.4	0.4
Total	215°	357.4°	87.7°	159.1°
Differential phase variation between two signals in passband				
S-band mixer (est.)	0.2	0.2	0.2	0.2
IF amp and BPF	8.4	8.4	8.4	8.4
Cable, IF	0.1	0.2	0.1	0.2
SSB and LPF	1.2	1.2	1.2	1.2
Video amp.	0.8	0.8	0.8	0.8
Total	10.7°	10.8°	10.7°	10.8°
Calibrator and pre/post cal				
Differential phase variation between two calibration signals				
Synthesizer	0.03	0.03	0.03	0.03
Cable, 1.8 MHz	0.06	0.12	0.06	0.12
Calibrator (est.)	0.04	0.04	—	—
Mixer, BPF (est.)	0.1	0.1	0.1	0.1
Phase meter (est.)	0.05	0.05	0.05	0.5
Total	0.28	0.34	0.24	0.30
Differential phase variation between the two calibration signals				
Calibrator (est.)	0.04	0.04	—	—
BPF and mixer (est.)	0.1	0.1	0.1	0.1
Phase meter (est.)	0.05	0.05	0.05	0.05
Total	0.2°	0.2°	0.15°	0.15°

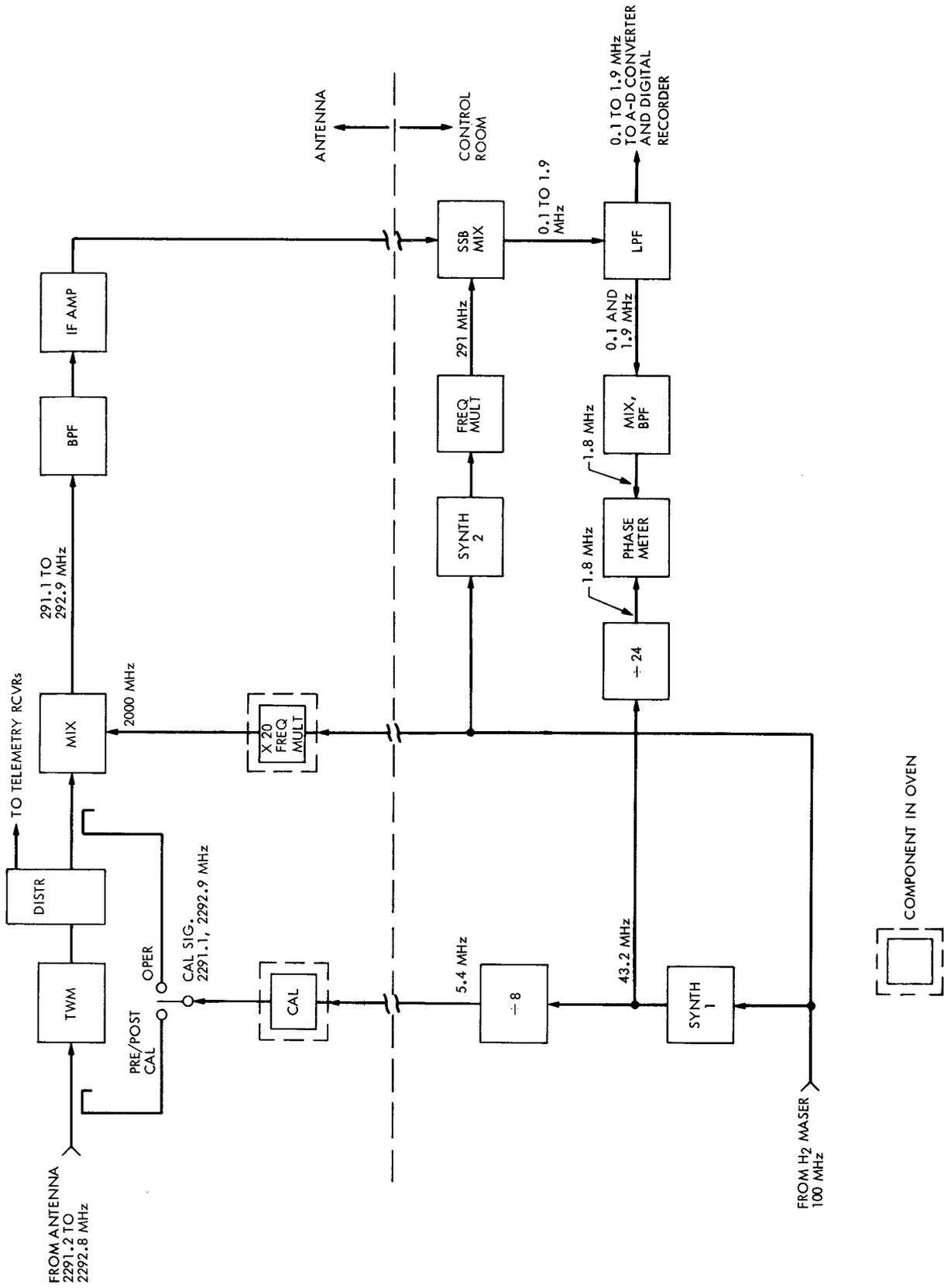


Fig. 1. DSN Wind Experiment Receiver

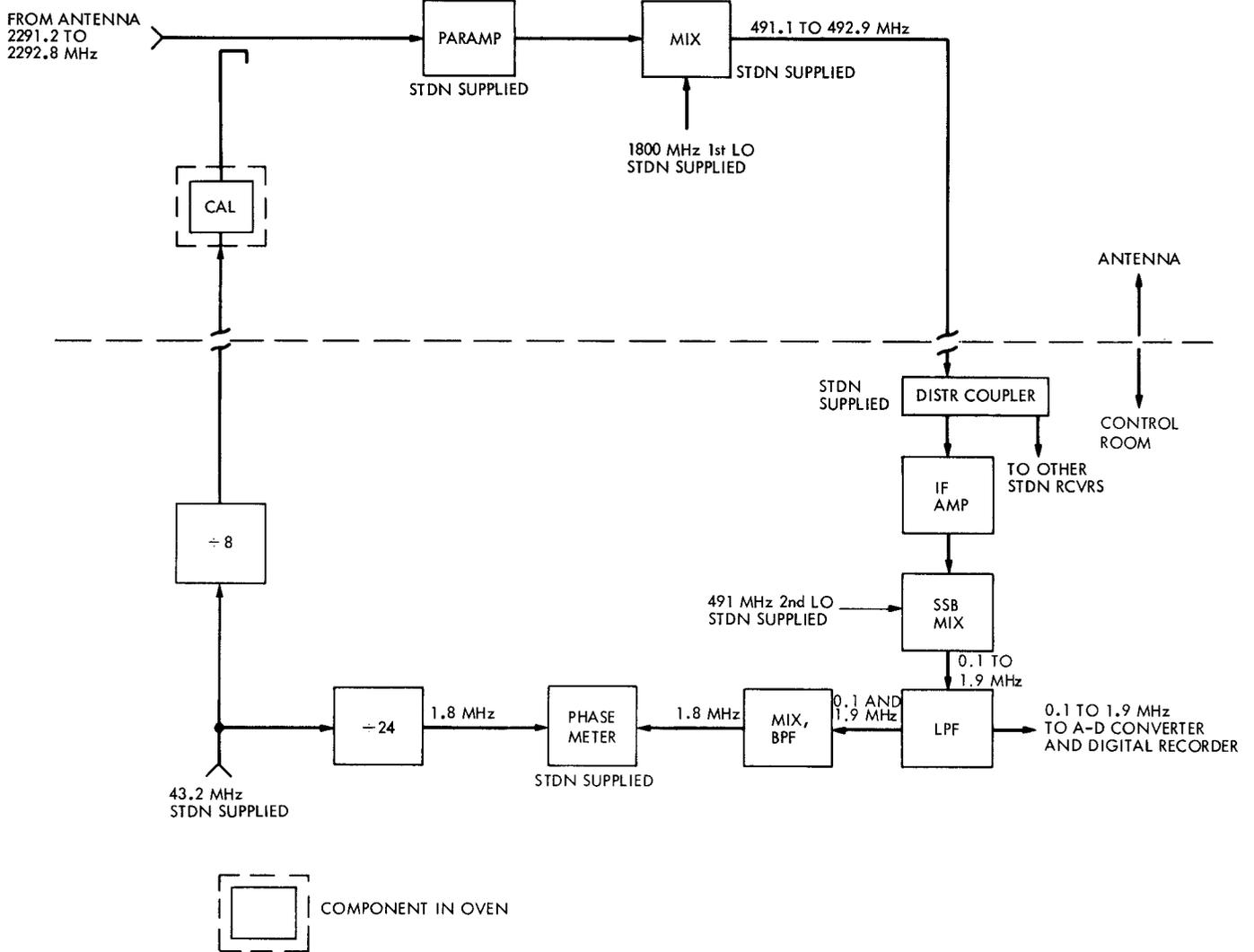


Fig. 2. STDN Wind Experiment Receiver